JOINT STRIKE FIGHTER

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Open Systems Architecture For JSF Avionics

30 April 1998

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Integrated Core Processor / Open Systems Architecture Lead

TOPICS

- Context For JSF Avionics Architecture
- Open System Principles for Embedded Real Time Processing
- JSF Avionics Architecture Definition (JAAD)
- System of Systems (SOS)
- Technology Obsolescence
- Summary

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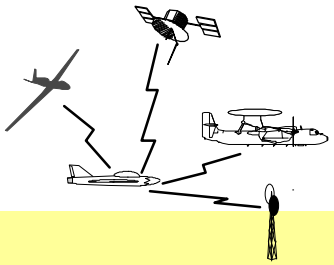
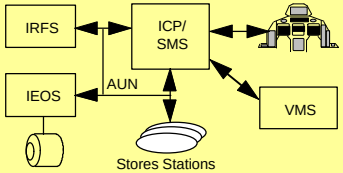
CONTEXT FOR JSF AVIONICS ARCHITECTURE: *ARCHITECTURAL HIERARCHY*

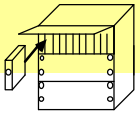


Level 1: Force Structure/ System of Systems

Level 2: Weapon System/ JSF



Level 3: Major Subsystem/ Avionics Suite



Level 4: Functional Area/ Integrated Core Processing

Level 5: Hardware/Software Building Block

Level 6: Hardware/Software Component

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CONTEXT FOR JSF AVIONICS ARCHITECTURE: *NATURE OF MODERN AVIONICS ARCHITECTURES*

- **Any System Architecture Must Address:**
  - **Functional Entities and Their Interfaces**
  - **Interconnects/Interaction Among Entities**
  - **Global Design Rules & System Attributes**
- **Open Systems Principles Provide Discipline For:**
  - **Functional & Physical Partitioning**
  - **Definition & Control of Interfaces & System Services**
  - **Appropriate Use of Standards (Preferably Commercial)**
- **Characteristics Include:**
  - **High Performance, Real Time Embedded Processing**
  - **Scalability**
  - **Technology Independence & Domain-Confined Timing**
  - **Information Security**
  - **Reliability, Maintainability & Fault Management**
  - **Partitioning for Affordable Upgrading & Testing:**
    - **Isolated Threads**
    - **Modular Packaging**
    - **OS Kernel**
    - **Memory Partitioning (page tables)**
    - **ORBs**
    - **Input Parameter Checking**

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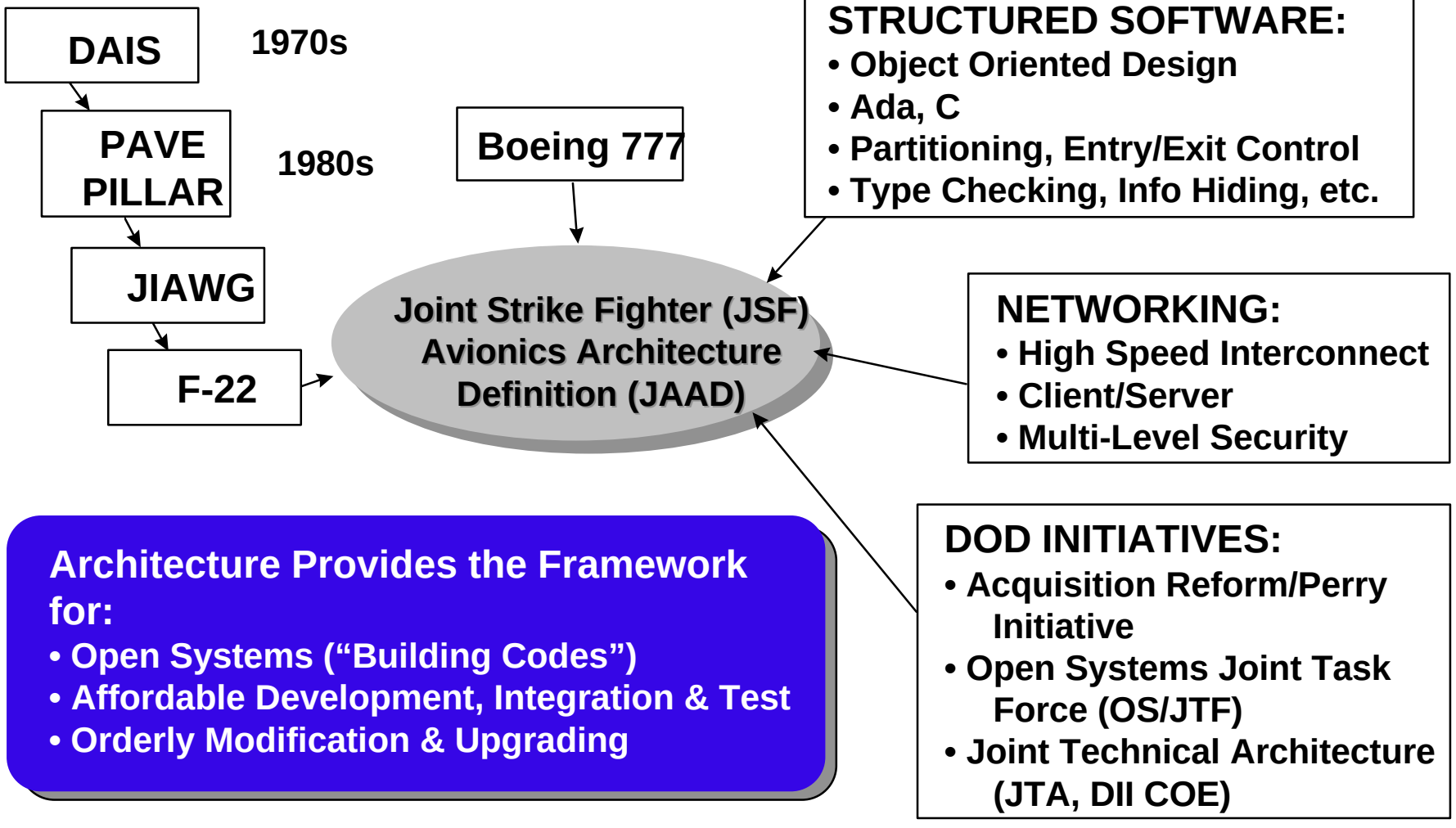
CONTEXT FOR JSF AVIONICS ARCHITECTURE:
LEGACY OF MODERN FIGHTER AVIONICS



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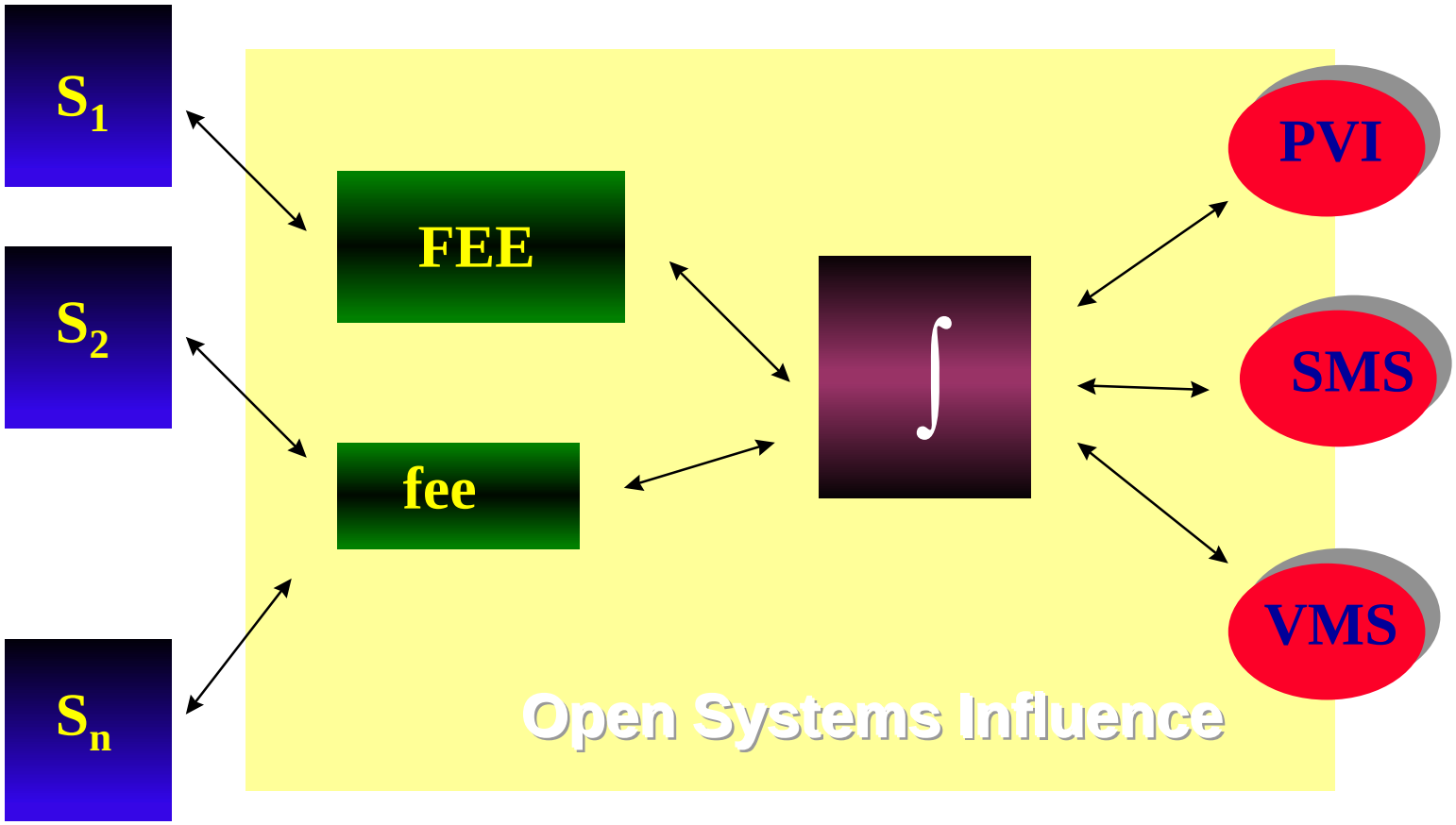
CONTEXT FOR JSF AVIONICS ARCHITECTURE:
GENERIC FIGHTER AVIONICS ARCHITECTURE



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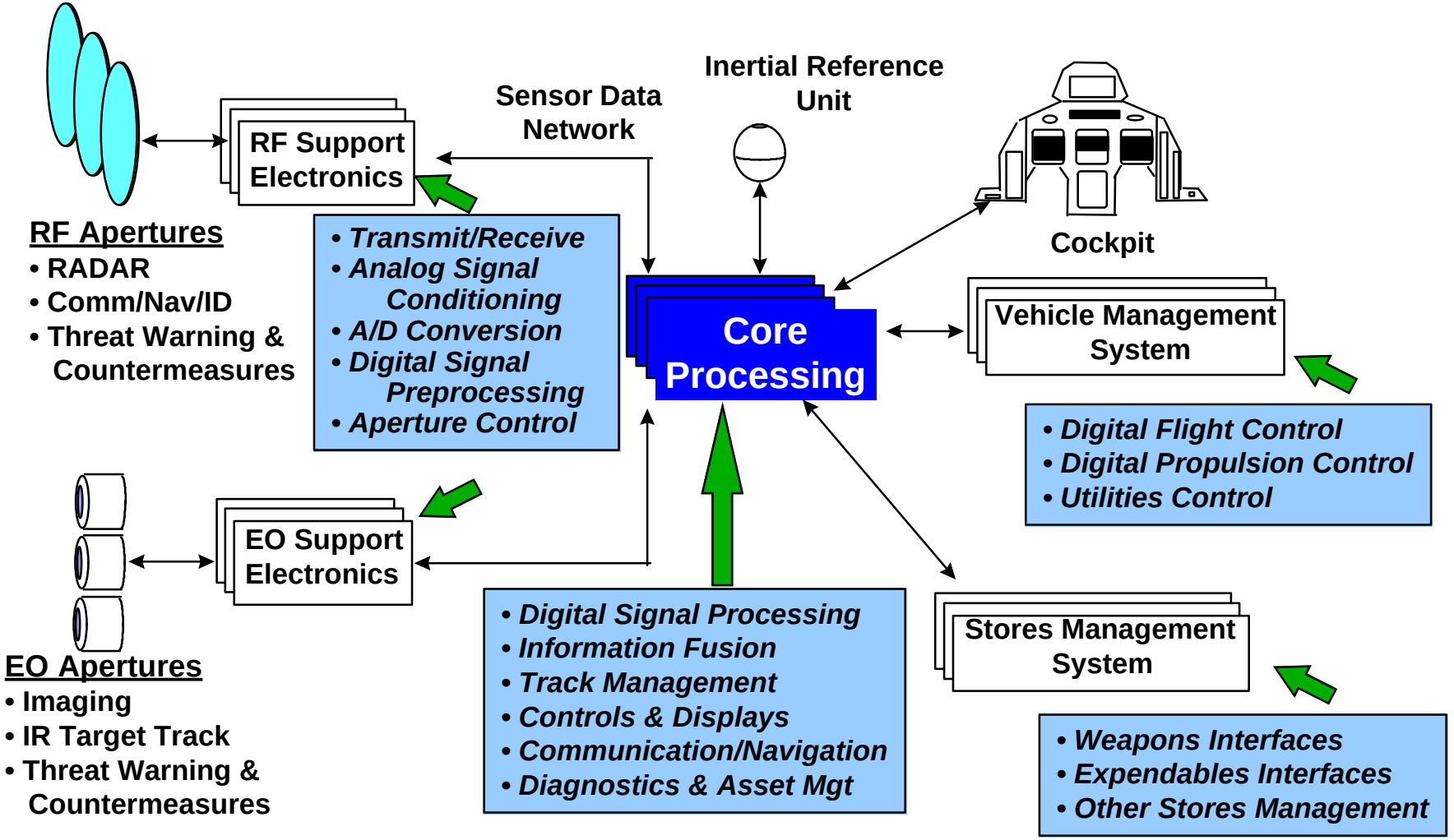
CONTEXT FOR JSF AVIONICS ARCHITECTURE: *STRUCTURE OF A MODERN FIGHTER AVIONICS SUITE*



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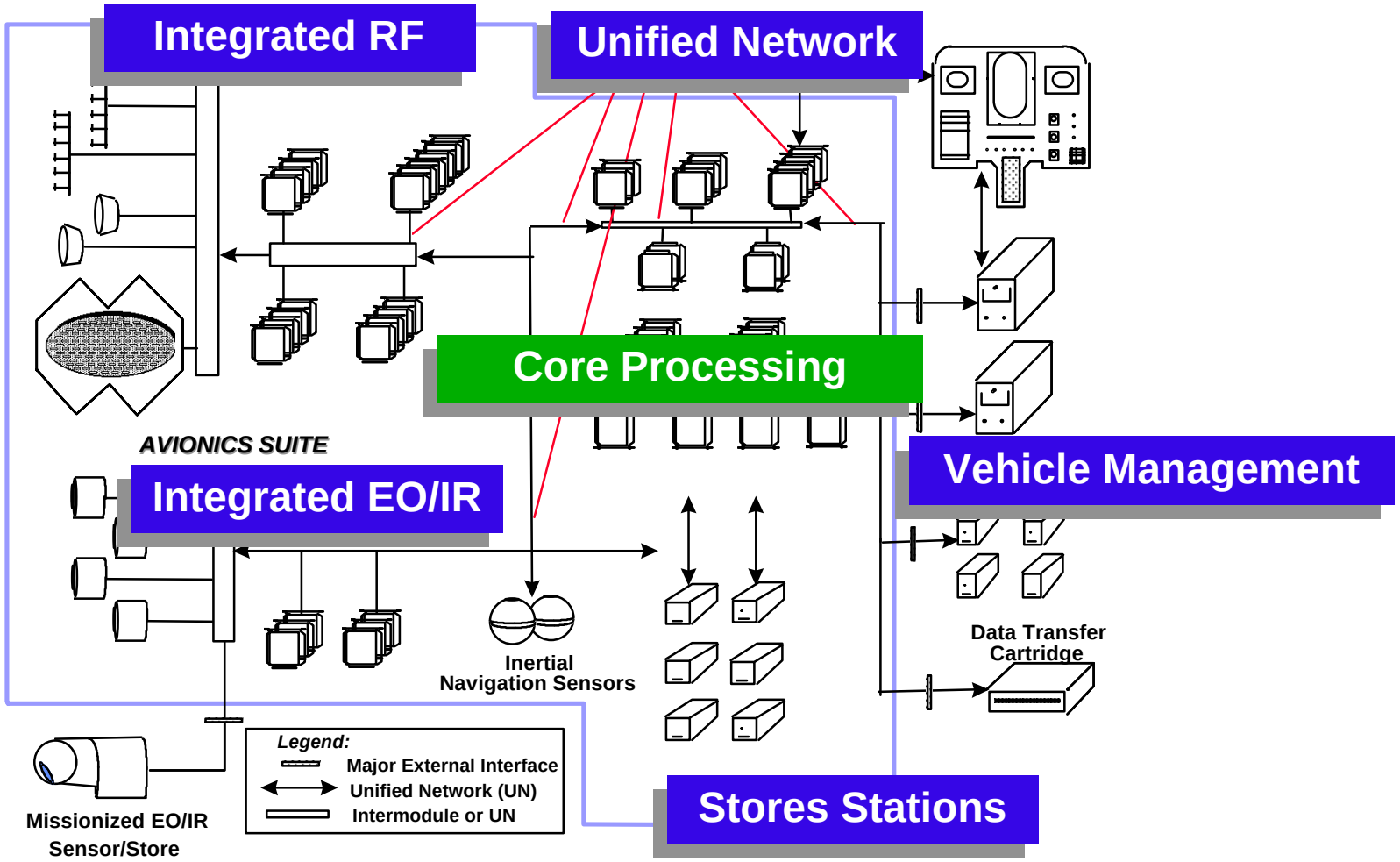
CONTEXT FOR JSF AVIONICS ARCHITECTURE:
JSF LEVEL 3 PARTITIONING



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CONTEXT FOR JSF AVIONICS ARCHITECTURE: *LESSONS LEARNED*

- **Open Systems Is Necessary but Not Sufficient to Achieve Long-term:**
  - **Performance & Support**
  - **Affordability**
  - **Interoperability With DoD**
  - **System of Systems**
- **Besides Open Systems, Program Strategy Must Enforce:**
  - **Software Engineering Discipline (i.e., S/SEE)**
  - **Rigorous Requirements Analysis**
  - **Contract Incentives to Optimize *System* Performance**
- **Functional Integration Must Only Occur At Selected Junctures Within the Architecture (e.g., Track Fusion Node) -- Physical Integration + Functional Federation**

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CONTEXT FOR JSF AVIONICS ARCHITECTURE: *LESSONS LEARNED* (CONTINUED)

- **Employ Open Systems Principles at the Outset**
- **Place Primary Emphasis on Interfaces & Common Services, *Not* Common Modules**
- **Adequate Risk Reduction and Demonstration of Candidate Technologies Before Standards Selection**
- **C^4 and Avionics Systems Face Many of the Same Open Systems Challenges -- Issues Addressed In Architectures May Differ**
- **A Technical Reference Model (TRM) is a Powerful Complement to Traditional Architecture Definitions**

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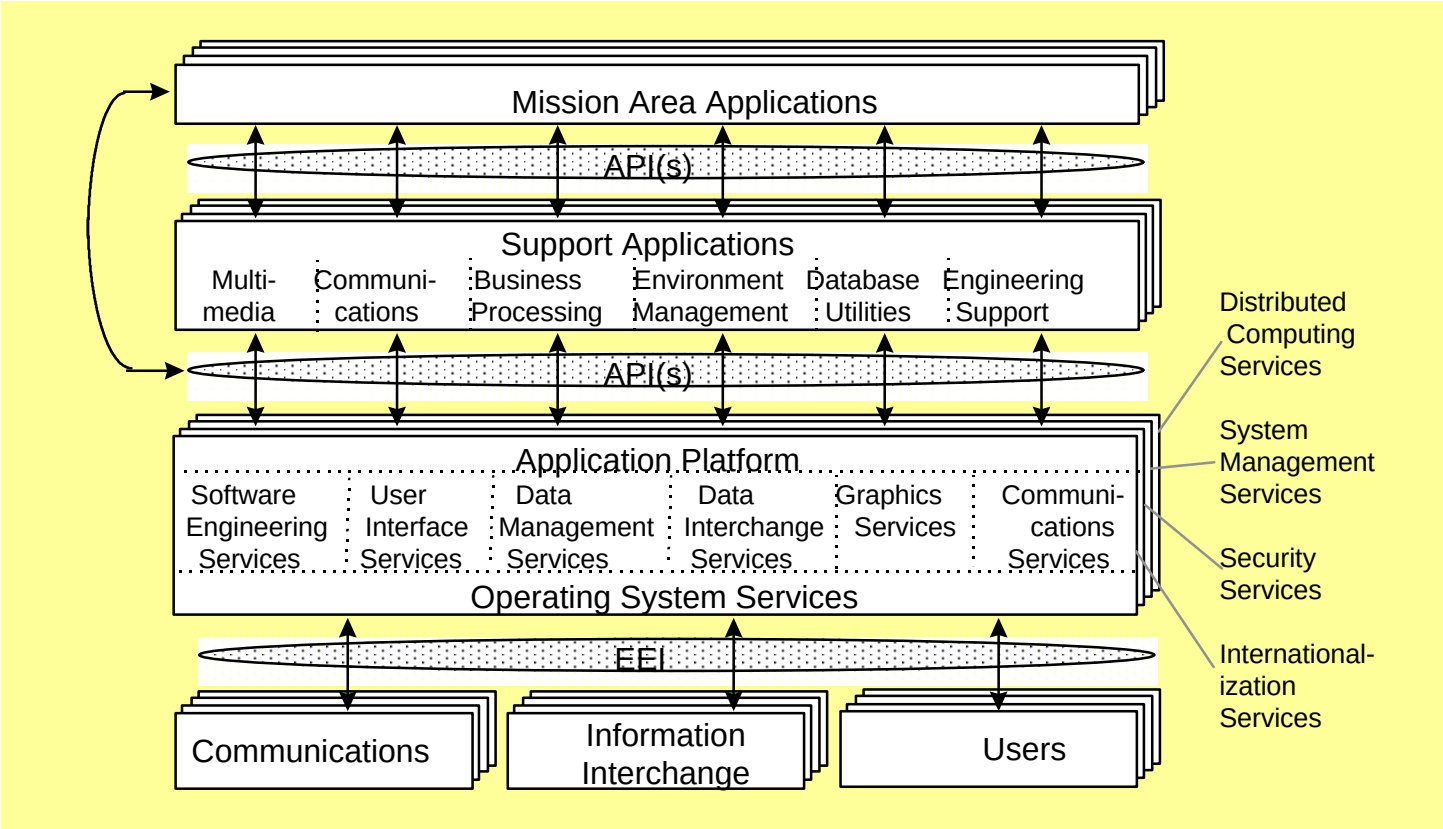
CONTEXT FOR JSF AVIONICS ARCHITECTURE:
DOD TRM, VERSION 3.0



- **A Key Underpinning of the JAAD**

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OPEN SYSTEM PRINCIPLES:
SOME KEY TERMS & CONCEPTS

- **Classes of Information Systems:**
  - **Management Information Systems:**
    - **Payroll, Purchasing, Personnel, etc. - All COTS**
    - **Large, Physically Dispersed, Non-Real Time**
    - **Classic Opportunity for Open Systems - Competitive Sourcing, Software Reuse, System Interoperability, etc.**
  - **Command, Control, Communications & Intelligence (C^3I):**
    - **Distributed/Parallel High Speed Processing w/ Mix of COTS & Custom Components**
    - **Operate in Non- or Soft Real Time**
    - **Major Benefits from Open Systems**
  - **Embedded:**
    - **Small, High Performance, Single Platform - COTS May be Limited**
    - **Real Time Operation - *HARD* Real Time for Flight & Mission-Critical Functions**
    - **Open Systems Strategy Must Meet Performance, Safety, Interoperability, & Other Requirements**

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OPEN SYSTEM PRINCIPLES: *SOME KEY TERMS & CONCEPTS* (CONTINUED)

- **Integration:**
  - **Physical Integration - Collocation/Interconnection of System Elements**
  - **Functional Integration - Information Sharing, Cooperative Functions, Redundancy, Centralized Resource Management, etc.**
- **Modularity:**
  - **Partitioning/Decomposition of System Resources into "Atomic" Building Blocks**
  - **Interfaces Among Modules at Various Levels of the System Hierarchy**
- **Commonality: Use of the Same Building Blocks Within and Among Systems**

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OPEN SYSTEM PRINCIPLES: *GENERAL ATTRIBUTES OF OPEN SYSTEMS* (CONTINUED)

- **Modular Design w/Mapping of Functions Onto Hardware & Software Components**
- **Mapping of Software Architecture Onto Hardware Architecture (a Block Diagram Is *NOT* an Architecture)**
- **Component Interfaces Which Are:**
  - **Fully Defined**
  - **Publicly Available**
  - **Maintained Through a Process of Expert Consensus**
  - **Implementable with Available Products**
- **Maximum Feasible Use of Mature, Well Supported, Widely Used Interface Standards**
- **Litmus Test Is Ability to Mix/Match/Integrate Modules from Multiple Sources**

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OPEN SYSTEM PRINCIPLES:
KEY AVIONICS ARCHITECTURE ISSUES AND TRADE-OFFS

- **Interconnects:**
  - **Unified Avionics Network Protocol**
  - **Required Performance to Support Information Flows**
- **Memory-Mapped vs. Message Passing Data Communications**
- **Integrated vs. Distributed Data & Signal Processing**
- **Processor Types (GP vs. SP Processors)**
- **Integrated vs. Single Purpose Apertures**
- **Real Time Operating System (RTOS) Characteristics & Software Building Codes (e.g., APIs)**
- **Software Language & Development Tools**
- **Isolated Functional Threads vs. Physically Federated Subsystems**

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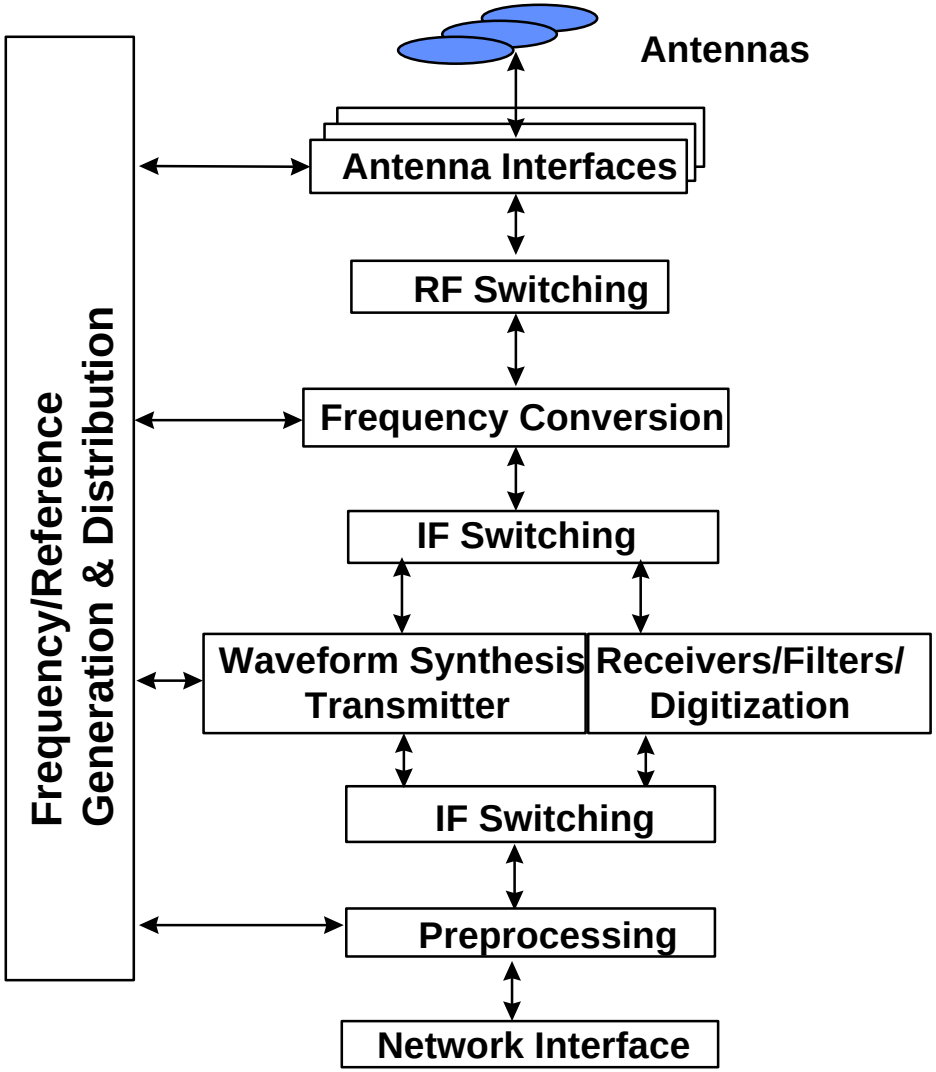
OPEN SYSTEM PRINCIPLES:
OPEN SYSTEMS APPLIES TO NON-DIGITAL FUNCTIONS



- **Partitioning & Interface Definitions**
- **Re-use of Common Building Blocks**
- **Selective Tech Insertion**
- **Competitive Sourcing**

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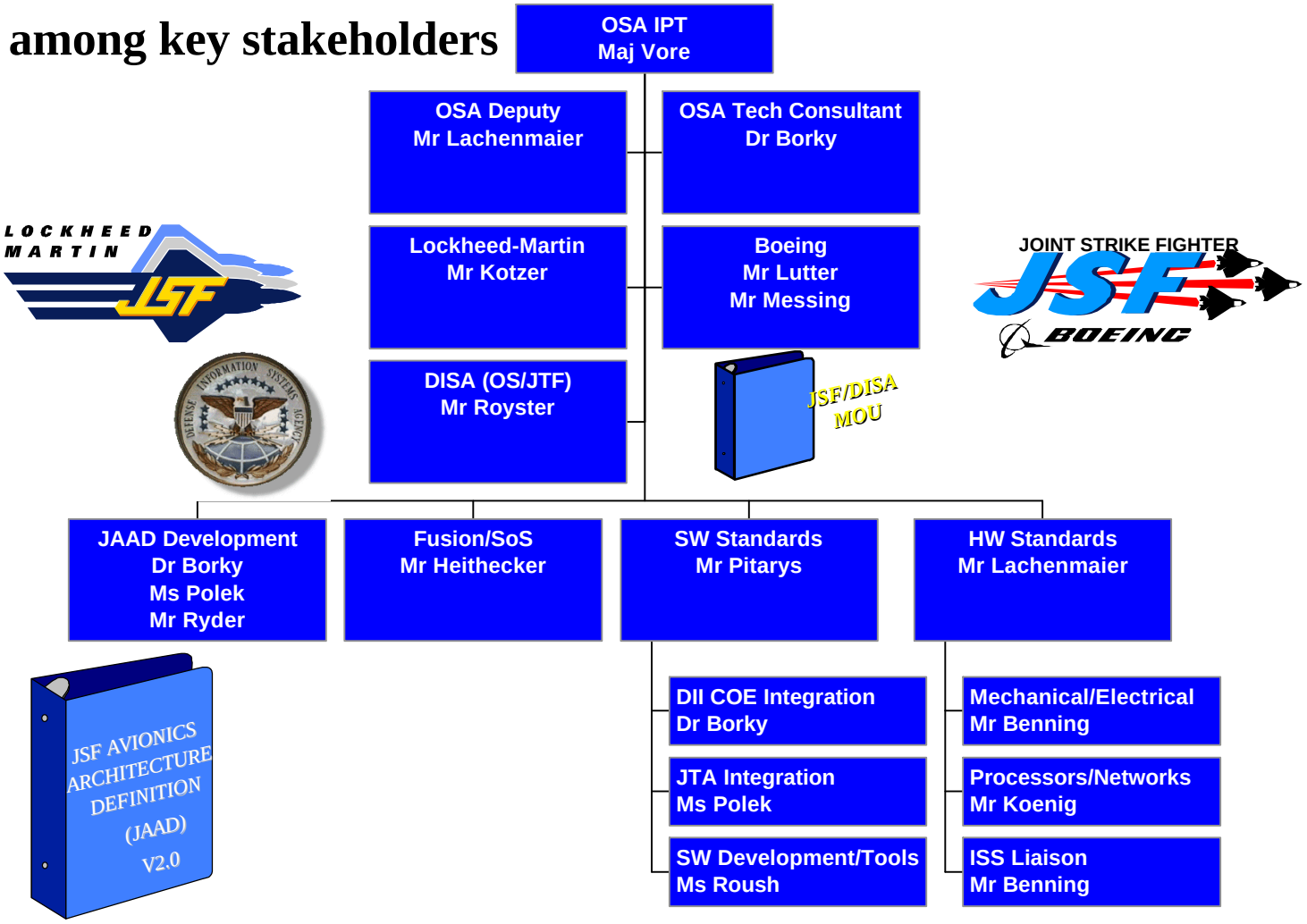
JAAD:
JSF OSA IPT ORGANIZATION

- **Teamwork among key stakeholders**



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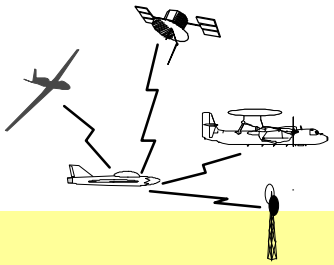
JSF AVIONICS ARCHITECTURE DEFINITION (JAAD): *ARCHITECTURAL HIERARCHY*



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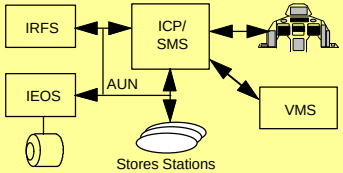

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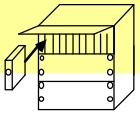

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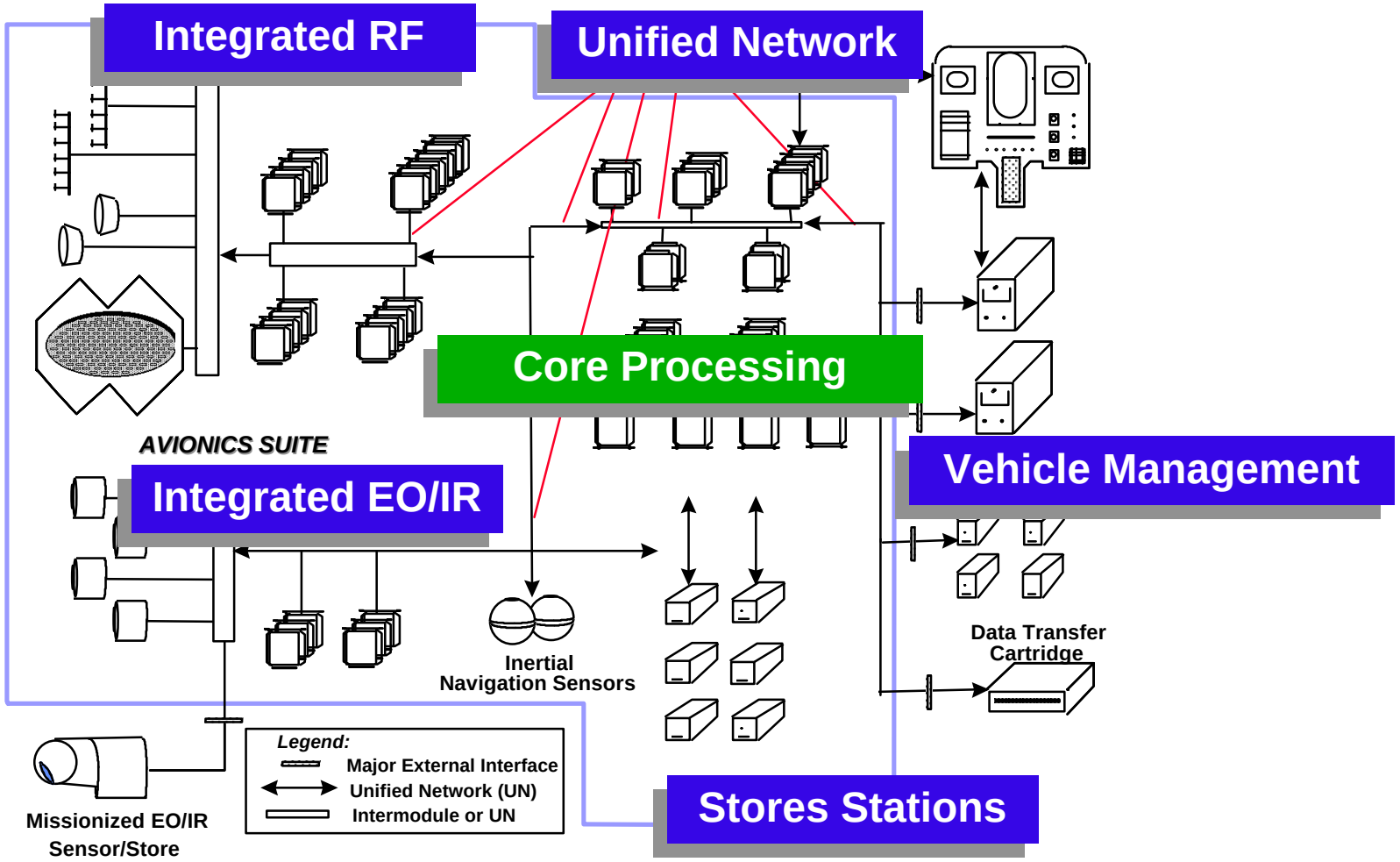
JSF LEVEL 3 PARTITIONING



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JAAD:
PRIMARY ISSUES FOR JSF ARCHITECTURE & ACQ STRATEGY

- **Cost of Module/Backplane Redesign For Tech Insertion**
  - **Module Design and Packaging Must Preserve COTS Benefits**
  - **Backplane Design Must Ensure Multi-generational Processor Replacements Within COTS Product Lines**
  -
- **Cost and Timeliness of Software Changes**
  - **Software Architecture Must Allow For Feature Insertion Or Extraction Within a Single Baseline OFP**
  - **Engineering Environment Must Merge and Automate Intermediate Steps Between Development and System-level Validation**
  - **Must Establish and Maintain Boundaries Around, and Eliminate Dependencies Among, Functions**
  - **Must Reduce Regression, Validation and Flight Test Times**

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JAAD:
PRIMARY ISSUES FOR JSF ARCHITECTURE & ACQ STRATEGY (CONT'D)

- **Cannot Afford Two Distinct Module Product Lines**
  - **Tech Insertion Must Integrate Fully With *Both* Production and Sustainment**
  - **R&M Improvements From Tech Insertion Must Be Reflected In Sustainment**

- **Cost Prohibitive to Port Among Differing Engineering & Support Environments**
  - **Single, Integrated S/SEE Across Contractor Team**
  - **Open Architecture Must Permeate System Infrastructure**
  - **Support Facilities Must Mirror Modular System Design**

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JAAD:
CHARACTERISTICS

- ***Spans Technical and System Architectures***
- ***Practical* Openness - Emphasis on Integration & Upgrading**
- ***Scalability* - Achieved by Modular Design & Overall Architecture**
- ***Domain Confined Timing* - Strict Localization of Critical Timing Relationships**
- ***Failure Management* - Embedded Diagnostics/Prognostics Plus Selective Redundancy**
- ***Unified Network* - Simplify Integration & Modification; Reduce Cost & Weight**
- ***F^3I* - Where "Function" is Defined as The Set of Behaviors Which a Module Can Exhibit Through Its Interface**
- ***Maximum Feasible Use of COTS & Commercial Standards***
- ***Support for the "ilities"* - Testability, Maintainability, etc.**

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JAAD:
PRIMARY BUILDING CODES

- **Connectivity:**
  - **Unified Network Protocol**
  - **Links to Other Platforms (“System of Systems”)**
- **Software:**
  - **Higher Order Language(s)**
  - **Real Time Operating System (RTOS) Services**
  - **Application Programming Interface(s) (APIs)**
  - **Graphics Interface**
  - **Data Base Management System Interface**
  - **Object Request Brokers (ORBs, if used)**
- **Mechanical/Electrical:**
  - **Packaging & Cooling**
  - **Power Distribution**

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JAAD:
PROVIDES EXAMPLE EVALUATION PROCESS FOR CANDIDATE STANDARDS

- **Initial Candidate Protocols for Unified Avionics Network**
  - **Asynchronous Transfer Mode (ATM)**
  - **Fibre Channel**
  - **Fibre Channel AE**
  - **Gigabit Ethernet**
  - **Myrinet**
  - **Scalable Coherent Interface (SCI)**
  - **SCI/Real Time**
  - **Serial Express**
  - **Sun S-Connect**

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JAAD:
ENABLERS OF KEY ISSUE RESOLUTION

ISSUE

- **Tech Insertion Cost**
  - **Reduce Module Redesign**
  - **Preservation of COTS**

"The contractor shall submit a plan for technology insertion which clearly demonstrates minimal or no cost of module or backplane redesign for incorporation of successive generations of commercial processors."

ENABLER

- **H/W Independence (API/OS)**
- **Modular Partitioning (F^3I)**
- **Executable Specifications**
- **Unified Network/Protocol**
- **On-module Features Reduce Backplane Complexity**
- **Processor Speeds Allow For General Purpose Application and Fewer Modules**
- **Incentivize Prime to Minimize Non-Recurring Cost of Module Design**

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JAAD:
ENABLERS OF KEY ISSUE RESOLUTION

ISSUE	ENABLER
• **Software/OFP Cost and Timelines** – **Single OFP Baseline** – **Responsiveness**	• **Re-Use of Objects and/or Components** • **Use of Structured Decomposition and Object-Oriented Design Approaches** • **Clean Segregation of Applications and Execution Platform via API** • **Replication of Environment Across The Team** • **Independent Funtional Threads and Controlled Fusion Processes** • **Functionality Implemented Via Data Versus Code**

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JAAD:
ENABLERS OF KEY ISSUE RESOLUTION

ISSUE	ENABLER
• Separate Module Production and Sustainment Lines	• Modular Architecture • HW Independence • Use Production Line For Sustainment
• Separate Engineering and Support Environments	• Portable SW and S/SEE • COTS OS, Processors and Networks Allow System Emulation On Development Stations

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JAAD:
ISSUES IN WORK FOR VERSION 3

- **Impact of & Compatibility with DoD Architecture Initiatives:**
  - **RT DII COE, JTA, GOA, AITS RA, etc., etc.**
  - **Overall Use of Object Request Broker (ORB) Construct**
  - **Common Operational Picture - NRO, DARO, NIMA, NSA, etc.**
- **Real Time Attributes - Possible Input to RT DII COE**
- **SOS Support Features:**
  - **Technical Complement to C^4ISR Support Plan**
  - **Definition of SOS from JSF Architectural Viewpoint**
  - **Possible Use of, Input to JTA**
- **Multi-Level Security (MLS)**
- **Prognostics & Health Management (PHM)**
- **Clear Linkage of Architecture To Issue Resolution**

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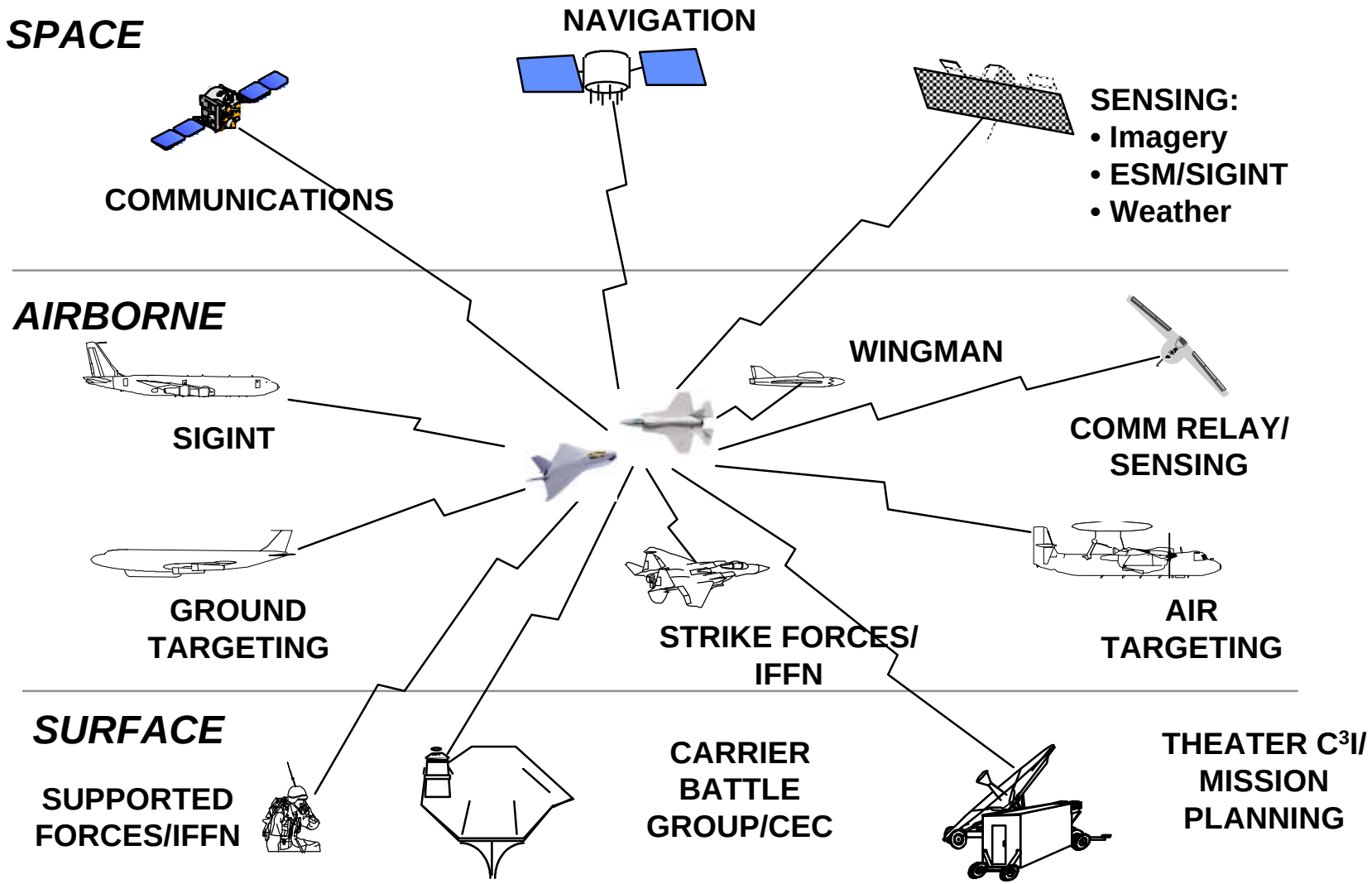
SOS:
CONTEXT FOR JSF



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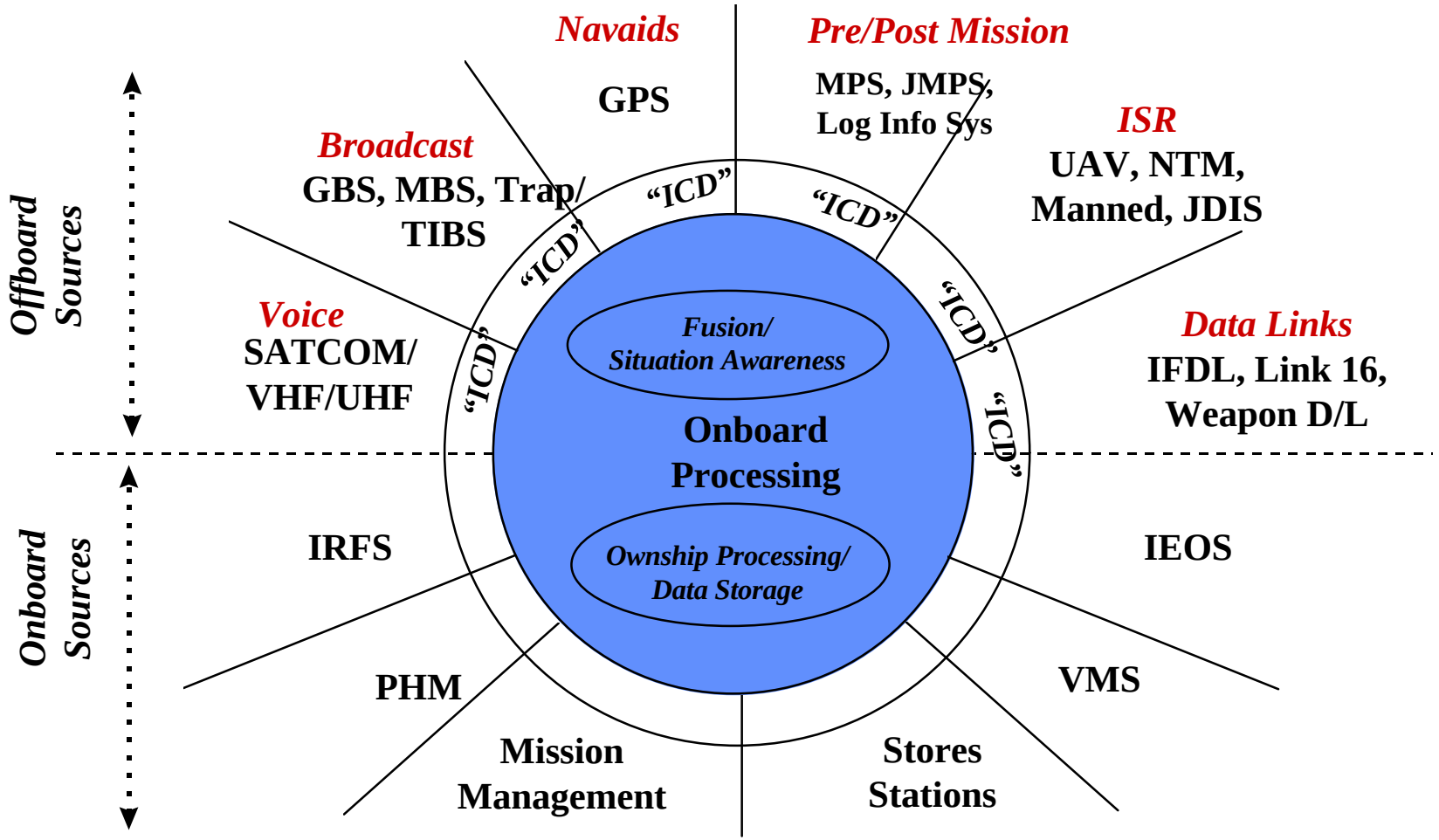
SOS:
EXTENDING THE BUILDING CODES FOR JSF OPEN SYSTEM ARCHITECTURE



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TECHNOLOGY OBSOLESCENCE:
ELEMENTS OF THE PROBLEM

- **Product Availability:**
  - **Commercial Life Cycles << Weapon System Development & Operational Lives**
  - **Every Inventory Weapon System Has Serious Obsolescence Problems**
  - **Virtually All Legacy Systems Experienced Nonavailable Parts Prior to 1st Flight**
- **COTS Survivability In Military Environments**
- **Rapid Change in Software Languages, Tools & Technologies**
- **Business Issues, e.g., Prime Contractor Wrap for CFE**
- **Acquisition Issues - Program Strategies & Costs To Mitigate Obsolescence (Open Systems is an up-front investment)**
- **Growth & Upgrading - Capability for Selective Modifications**
- **Budget Issues - ROI Requirements for "ilities" Mods; Multiyear Upgrade Programs; "Color of Money;" etc.**
- **Organic Depot vs. Contractor Responsibility**
- **Multi-Service/Multi-National Configuration Management**
- **Optimizing Individual Systems vs. Common Solutions**
- **Life Cycle Cost Dominated by Software & Non-Digital Hardware**

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TECHNOLOGY OBSOLESCENCE:
BASIC APPROACH TO MITIGATION

- **Must Address Two Distinct Aspects of the Problem:**
  - ***Affordability*** **in Development, Acquisition, & Logistics Support**
  - ***Availability*** **to Maintain Readiness & Operational Support**
- **Ultimate Goal:**
  - **Technology-Independent Design Capture**
  - **Implementation with Available Products When Needed**
  - **Maximum Use of CAE for Specification Compliance Testing, Design Verification, System Integration, etc**
- **Continuing R&D Throughout Life of Program**
  - **Evaluate and Demonstrate Applicability of New Technologies**
  - **Analyze & Correct Performance & Supportability Shortfalls**
  - **Capitalize on Up-Front Investment In Open Systems**
  - **In short, *Do* Evolutionary Acquisition**

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TECHNOLOGY OBSOLESCENCE: *BASIC APPROACH TO MITIGATION* (CONTINUED)

- **Traditional Approaches (Useful In Specific Instances, *Not* a Preferred Solution):**
  - **Lifetime Parts Buys**
  - **Reverse Engineering for Suitable Substitutions**
  - **P^3I & Modification/Replacement of Unsupportable Systems/Subsystems**
- **Architectural Strategies - Open Systems, Clean Partitioning & Domain-Confined Timing**
- **Executable Design Specifications:**
  - **Separate Function from Point Design**
  - **CEENSS (Continuous Electronics Enhancement using Simulatable Specifications)**

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SUMMARY:
ELEMENTS OF A STRATEGY

- **Specify Architectural Attributes, Not Design Specifics**
- **Require Offerors to Describe Approaches/Methodologies:**
  - **System & Software Engineering/Integration/Test**
  - **Compliance/Certification for Applicable Attributes**
  - **Subcontractor Management/Incentives for System-Level Optimization**
- **Use Executable Specifications - Capture Design & Functionality Unambiguously as Simulation Objects**
- **Enforce Rigorous Modular Decomposition with Traceability Up and Down the Hierarchy**
- **Ensure Functional Definitions Are Complete and Technology-Independent**
- **Selectively Apply COTS & Commercial Standards**
- **Use Results of Early Virtual Engineering As Foundation for System Integration Lab For Life of System**

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SUMMARY:
OPEN SYSTEMS IS KEY TO JSF ACQUISITION STRATEGY

- **Physical Integration, Functional Federation Is Essential to Performance, Mission Reliability, Supportability & Affordability**
- **Fighter Avionics Shares Many of the Same Challenges As Those Seen in C^4ISR Systems**
- **Open Systems is a Key Enabler for JSF To Operate In the DoD "System of Systems" Context**
- **Open Systems Enables Ease of Upgrade, Reduced Testing, and Long Term Viability via Modularity**
- **COTS-Based Components and Standards Can be Major Contributors to Mitigating Technology Obsolescence**
- **The JAAD Presents a Framework for Avionics Concept Refinement, Technology Maturation, Conformity to DoD Architectural Standards & Development of Building Codes:**
  - **General Principles & Attributes**
  - **Overall Structure & Context for Application of Standards**

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JOINT STRIKE FIGHTER

The Next Generation Strike Fighter

Backups

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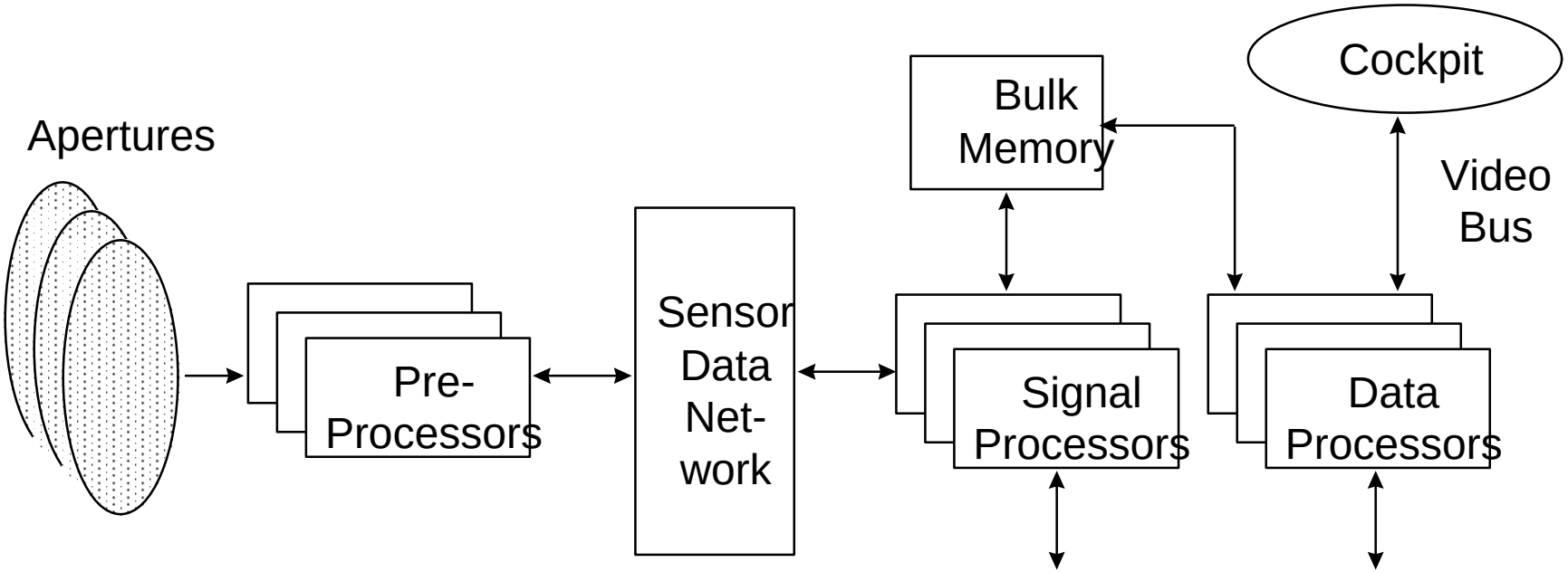
PAVE PILLAR



Other Interfaces:

- MIL-STD 1553B
- Avionics - Vehicle Management System
- Avionics - Stores Management System

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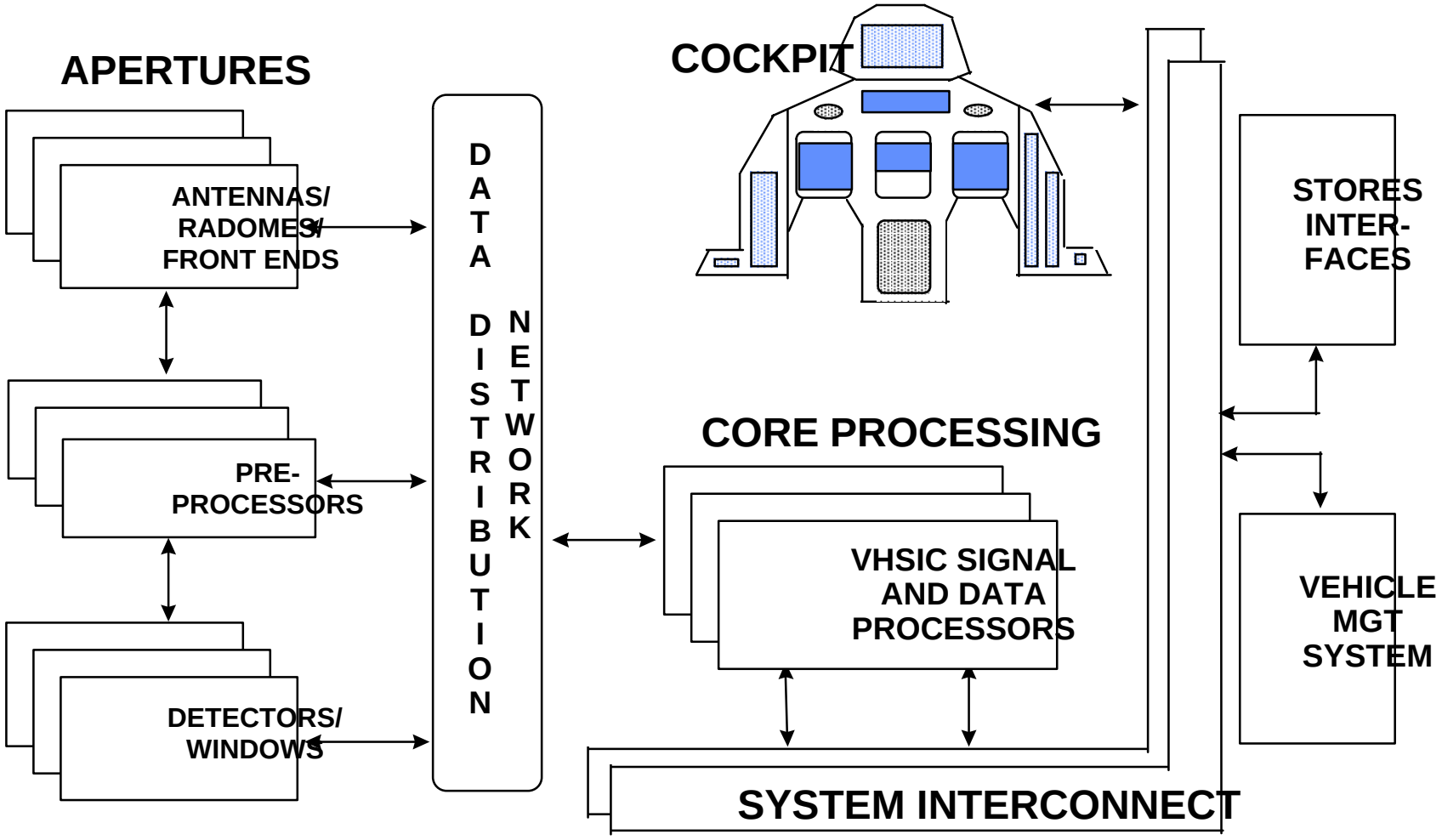
JIAWG ADVANCED AVIONICS ARCHITECTURE



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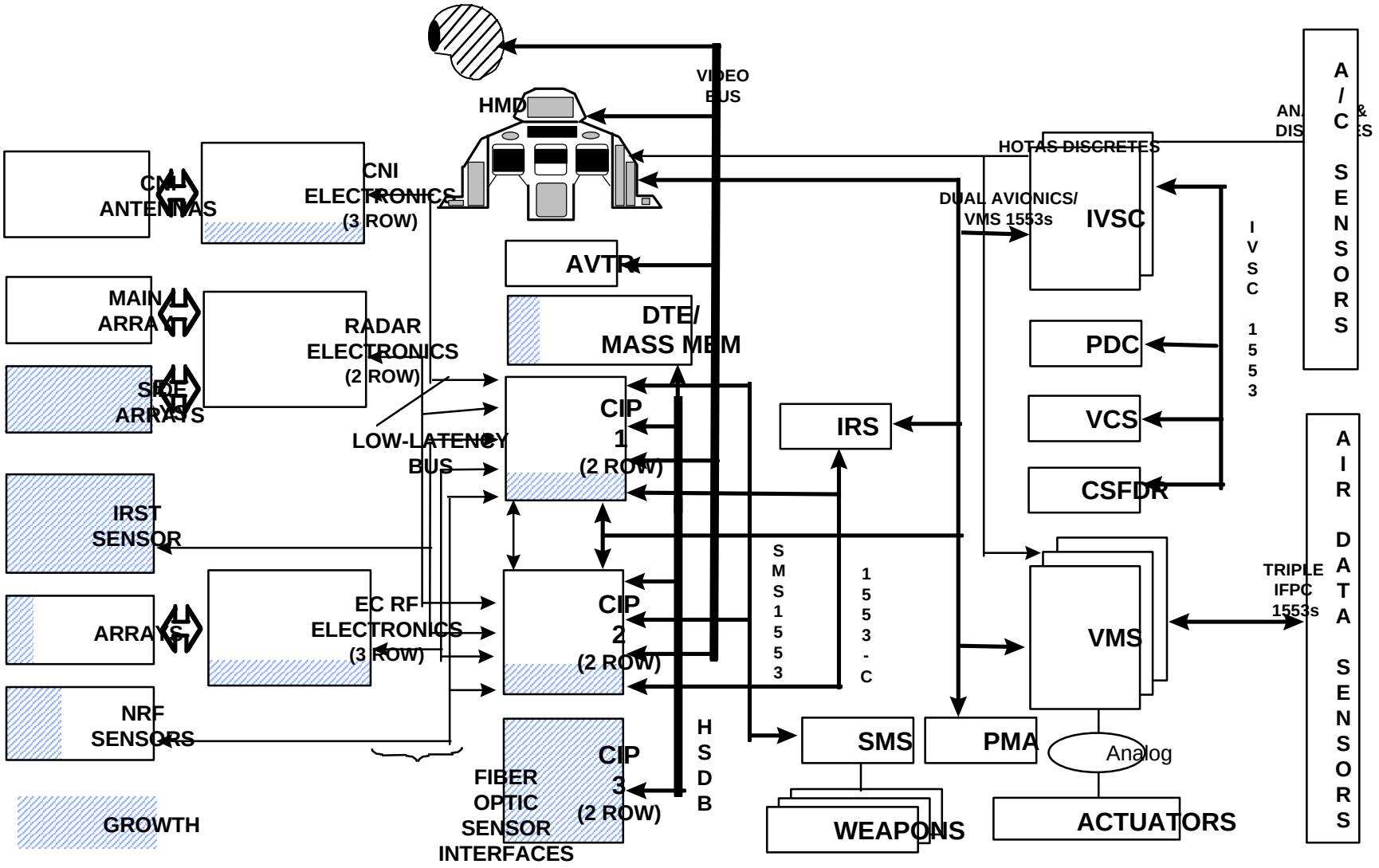
F-22 ARCHITECTURE



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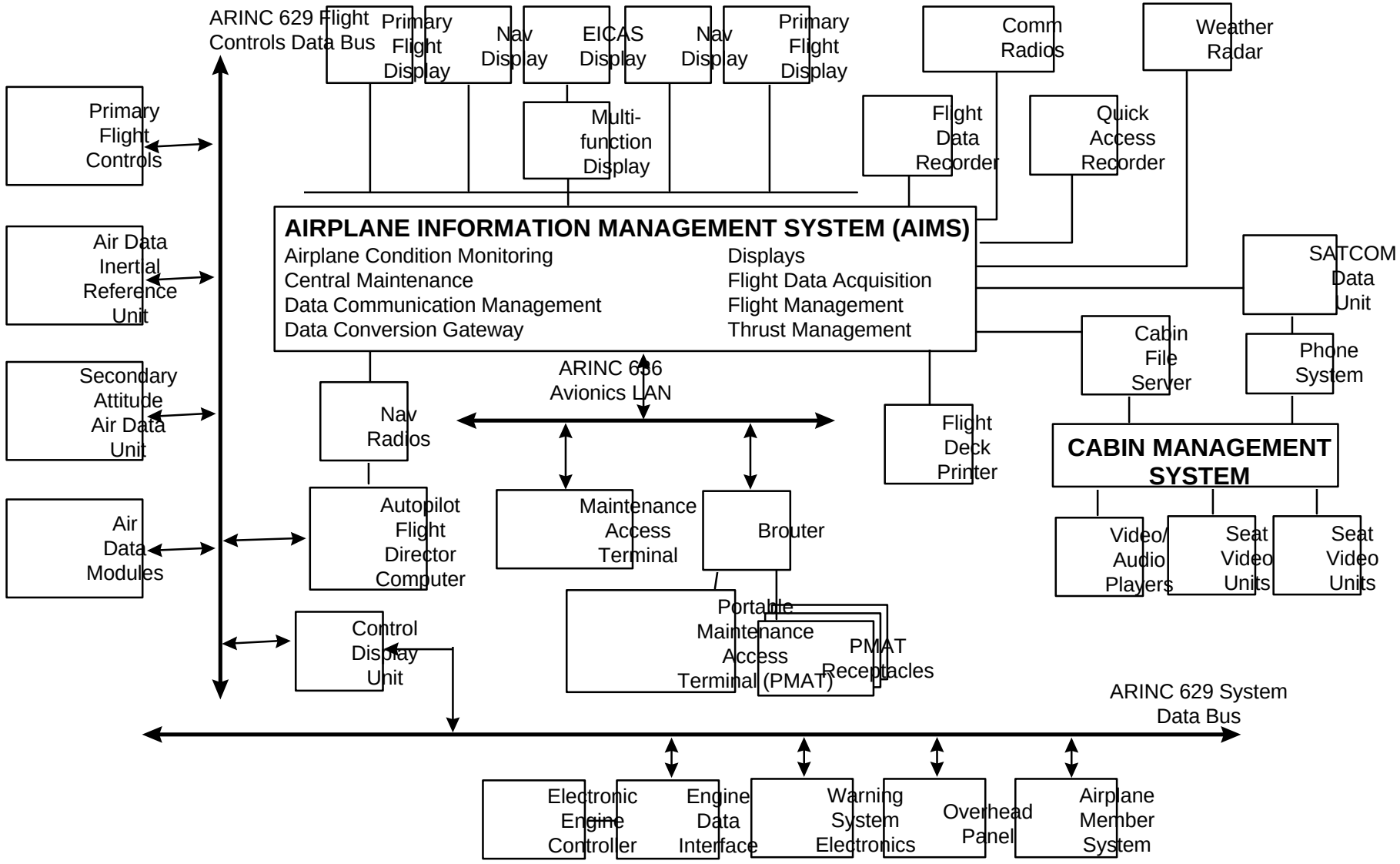
B777 SYSTEM ARCHITECTURE



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OPEN SYSTEM PRINCIPLES: *SOME KEY TERMS & CONCEPTS* (CONTINUED)

- **Architecture:**
  - **Categories in the Joint Technical Architecture (JTA):**
    - **Operational Architecture - User Requirements**
    - **System Architecture - Three Elements:**
      - **System Components or Resources**
      - **Interactions/Relationships Among Resources**
      - **Global Rules for Design, Operation, & Evolution**
    - **Technical Architecture - Services, Interfaces, Standards & Other Rules & Conventions**

    JAAD
  - **Common Operating Environment (COE) Under the Defense Information Infrastructure (DII) - Defines an Execution Environment & Set of System Services for Use by Applications**
  - **Technical Reference Model (TRM):**
    - **Establishes the Structure of and Relationships Among Software Entities - Applications, Execution Platform, & Interfaces**
    - **These Functions Must Be Mapped Onto a Hardware Architecture**

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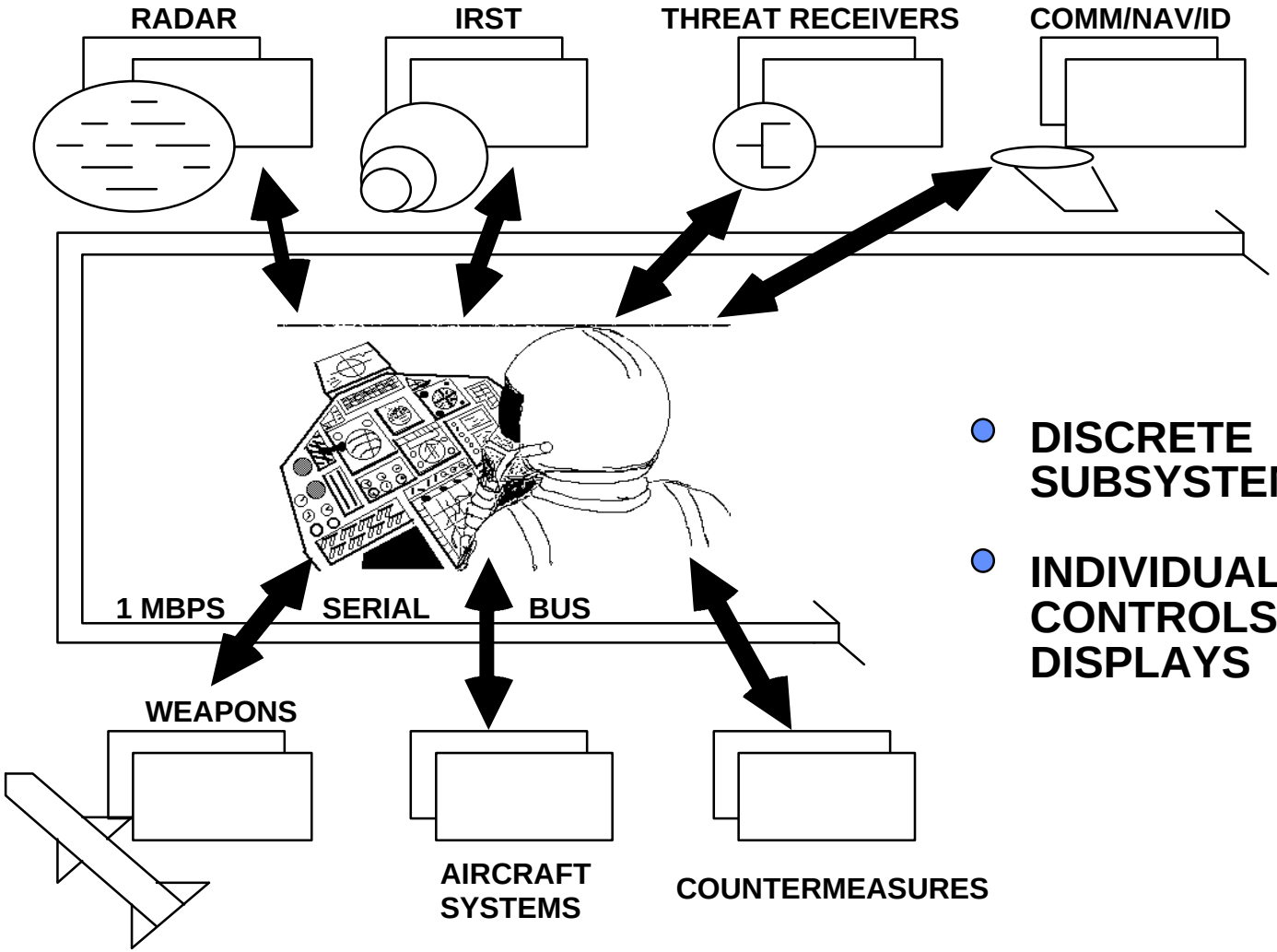
FEDERATED AVIONICS



- DISCRETE SUBSYSTEMS
- INDIVIDUAL CONTROLS & DISPLAYS

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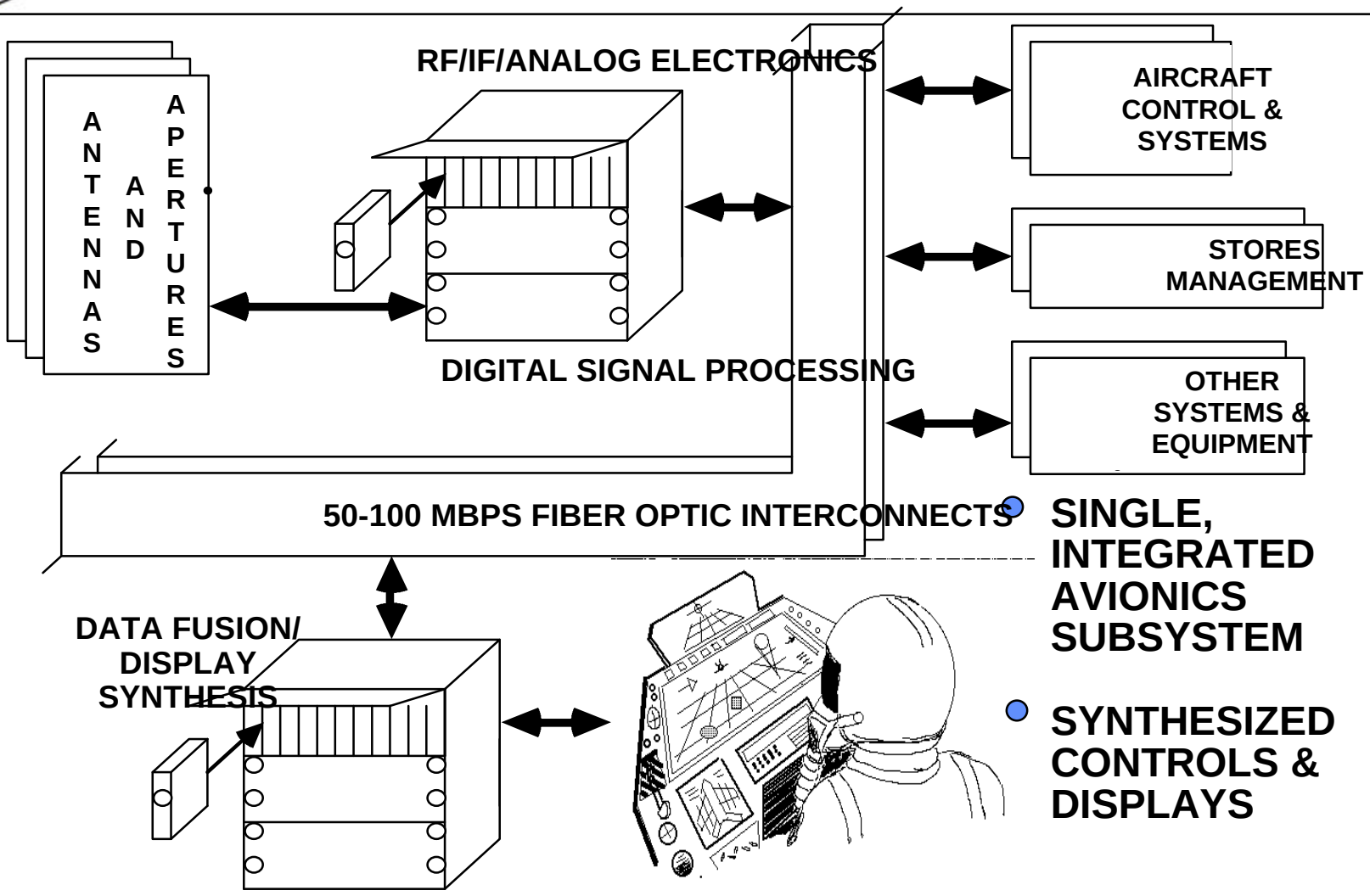
INTEGRATED AVIONICS



- SINGLE, INTEGRATED AVIONICS SUBSYSTEM
- SYNTHESIZED CONTROLS & DISPLAYS

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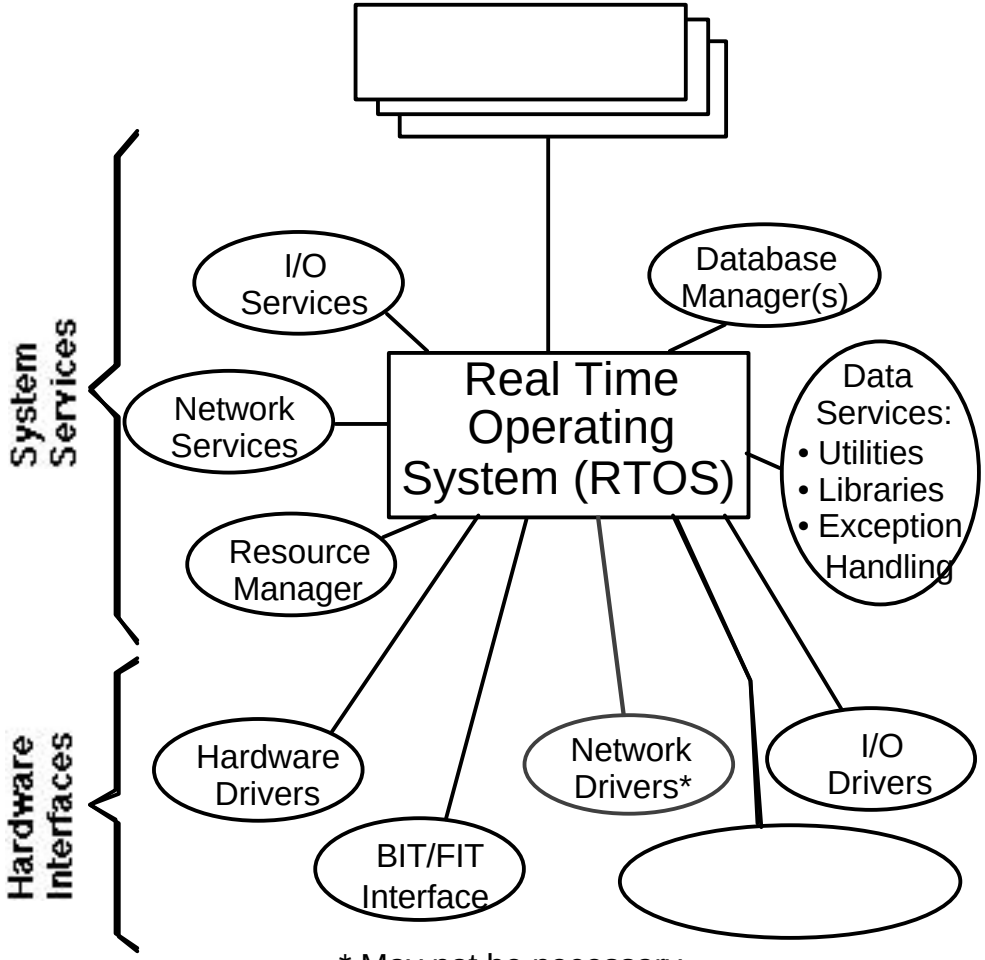
JAAD SOFTWARE PARTITIONING



* May not be necessary.

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